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Developing a Value of Information (Vol)- Enabled System from Collection to Analysis

**by Mark R Mittrick, John T Richardson, Alex Vertlieb, and
Timothy P Hanratty**

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Developing a Value of Information (VoI)- Enabled System from Collection to Analysis

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1. Introduction

Developing and sustaining situational awareness is an enduring challenge for today's Warfighter.¹ Situational awareness, or knowledge of the immediate present environment, is a daunting task considering the plethora of data sources available. In particular, an intelligence analyst must be able to search through an enormous haystack in a timely manner to find the few valuable needles. The US Army Research Laboratory (ARL) has confronted this challenge by researching and developing the Value of Information (VoI) metric.²

The VoI metric uses a fuzzy logic-based model that converts the subjective experience of subject matter experts (SMEs) into a range of scores. Specifically, given an evaluation of the source reliability and information content of an intelligence report, the ARL model will produce a VoI score that approximates the SME process for determining value. Hypothetically, this score will enable an intelligence analyst to identify the most valuable information necessary to sustain situational awareness. Simulations conducted by ARL have demonstrated that the VoI metric can increase the situational awareness of an intelligence analyst during a finite time period.³

In this report, we discuss a prototype system that pushes VoI beyond simulations and into the field environment where further research can be conducted. In general, the system consists of VoI-enhanced 1) collection tool, 2) dissemination service, and 3) visual analytic. The collection tool developed by ARL will be embedded with a Soldier that will enable them to create and disseminate VoI-rated reports. In this scenario, the Soldier is the data collector and SME. Their subjective evaluation of the of collected intelligence initiates the VoI rating that will persist all the way to the analyst. The dissemination service leveraged in this prototype is DSPPro, software that was developed by the Institute for Human and Machine Cognition (IHMC) in collaboration with ARL. Finally, the visual analytic for this prototype is an enhanced version of Contour (a relationship discovery tool developed by Decisive Analytics Corporation). The ARL enhancements to Contour use the VoI rating of the source data as a means of filtering the relationship diagram. The development and integration of each component will be discussed in detail in the proceeding sections.

In conclusion, the goal of this research is to develop a prototype system that will allow ARL to evaluate VoI in a field environment. Simulations already suggest that VoI is a candidate for helping sustain situational awareness, but field experiments are necessary for further evidence. This prototype provides VoI enhancement at all stages from collector to analyst and can be used as a field experimentation platform.

2. Developmental Work

This section outlines the software development necessary for building the prototype. Development for this prototype included the creation of 2 Android smartphone applications (apps) and the enhancement of an existing tool (Contour).

Prior work with Android smartphone apps was leveraged to quickly develop both apps.⁴ This allowed for more time to test and refine the prototypes, which resulted in a superior end product.

Enhancing Contour with VoI functionality presented a unique challenge since the system was largely a black box with no source code available. With help from one of the original developers (Scott Martin, Decisive Analytics Corporation), VoI and Contour were successfully integrated.

2.1 Spot Report App

The Spot Report app was developed to report observations from the field that could have an immediate and significant effect on current planning and operations. The Soldier using the app will also subjectively assign a VoI score (Fig. 1) to the report. Finally, the report is disseminated to analysts for further evaluation. Please see the smartphone app workflow diagram (Fig. 2) for the complete process.

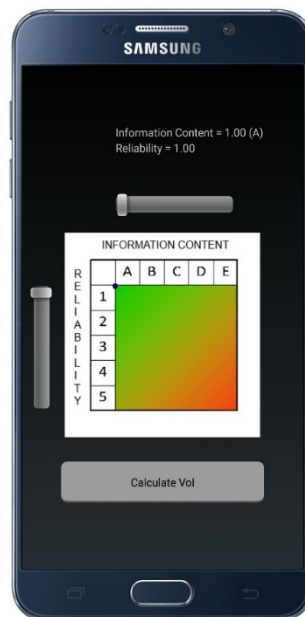


Fig. 1 Spot report main screen

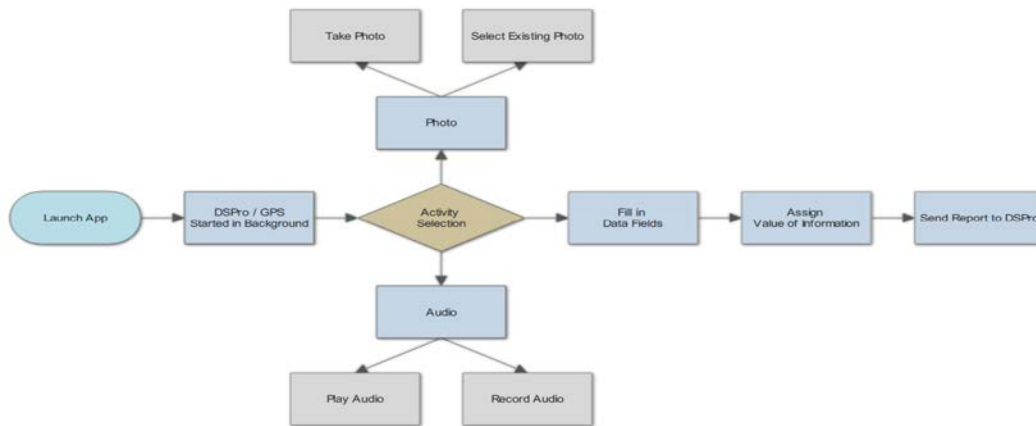


Fig. 2 Smartphone app workflow

To begin, the Soldier launches the app and is presented with the main screen (Fig. 3), where report content is recorded.

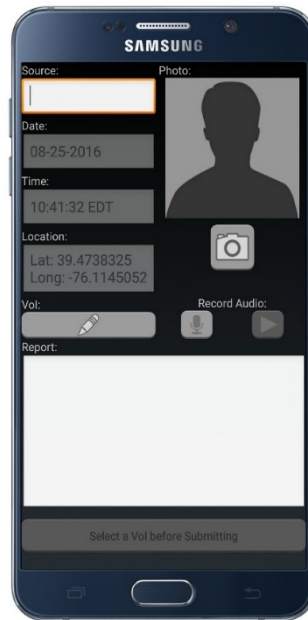


Fig. 3 VoI screen

The app was designed with simplicity and ease of use in mind, consequently some data are automatically generated using the smartphone's built-in capabilities. These fields (Date, Time, and Location) are intentionally greyed out to signify that they cannot be manually edited. The remaining fields (Source, Report, Picture, Audio, and VoI) are editable and the Soldier may complete any combination of fields before submitting the report.

The following is an example of output disseminated from the Spot Report app (DSPro required Extensible Markup Language [XML] format).

```

<?xml version="1.0"?>
<Metadata>
  <Field>
    <FieldName>Message_ID</FieldName>
    <FieldValue></FieldValue>
  </Field>
  <Field>
    <FieldName>Receiver_Time_Stamp</FieldName>
    <FieldValue></FieldValue>
  </Field>
  <Field>
    <FieldName>Referred_Data_Object_Id</FieldName>
    <FieldValue>APG</FieldValue>
  </Field>
  <Field>
    <FieldName>Referred_Data_Instance_Id</FieldName>
    <FieldValue>b79c56f3-7d27-4f38-addc-d719911daf38</FieldValue>
  </Field>
  <Field>
    <FieldName>Pedigree</FieldName>
    <FieldValue></FieldValue>
  </Field>
  <Field>
    <FieldName>Refers_To</FieldName>
    <FieldValue>NO_REF_OBJ</FieldValue>
  </Field>
  <Field>
    <FieldName>Prev_Msg_ID</FieldName>
    <FieldValue>DSPPro-ARL,DSPPro.CheckpointReport:SAMSUNG-SM-N900A:5</FieldValue>
  </Field>
  <Field>
    <FieldName>Source</FieldName>
    <FieldValue>SAMSUNG-SM-N900A</FieldValue>
  </Field>
  <Field>
    <FieldName>Source_Time_Stamp</FieldName>
    <FieldValue>1462300559853</FieldValue>
  </Field>
  <Field>
    <FieldName>Expiration_Time</FieldName>
    <FieldValue>0</FieldValue>
  </Field>
  <Field>
    <FieldName>Relevant_Missions</FieldName>
    <FieldValue></FieldValue>
  </Field>
  <Field>
    <FieldName>Left_Upper_Latitude</FieldName>
    <FieldValue>39.473900</FieldValue>
  </Field>
  <Field>
    <FieldName>Left_Upper_Longitude</FieldName>
    <FieldValue>-76.114532</FieldValue>
  </Field>

```

```

</Field>
<Field>
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  <FieldValue>39.473900</FieldValue>
</Field>
<Field>
  <FieldName>Right_Lower_Longitude</FieldName>
  <FieldValue>-76.114532</FieldValue>
</Field>
<Field>
  <FieldName>Location</FieldName>
  <FieldValue>Lat: 39.47390078
    Long: -76.11453237</FieldValue>
</Field>
<Field>
  <FieldName>Importance</FieldName>
  <FieldValue>9.330000</FieldValue>
</Field>
<Field>
  <FieldName>Source_Reliability</FieldName>
  <FieldValue>1.000000</FieldValue>
</Field>
<Field>
  <FieldName>Information_Content</FieldName>
  <FieldValue>1.000000</FieldValue>
</Field>
<Field>
  <FieldName>Data_Content</FieldName>
  <FieldValue>Spot_Report</FieldValue>
</Field>
<Field>
  <FieldName>Data_Format</FieldName>
  <FieldValue>image/jpeg</FieldValue>
</Field>
<Field>
  <FieldName>Target_ID</FieldName>
  <FieldValue></FieldValue>
</Field>
<Field>
  <FieldName>Target_Role</FieldName>
  <FieldValue></FieldValue>
</Field>
<Field>
  <FieldName>Target_Team</FieldName>
  <FieldValue></FieldValue>
</Field>
<Field>
  <FieldName>Classification</FieldName>
  <FieldValue>Unclassified</FieldValue>
</Field>
<Field>
  <FieldName>Description</FieldName>
  <FieldValue>Spot Report App</FieldValue>

```

```

</Field>
<Field>
  <FieldName>Node_Type</FieldName>
  <FieldValue></FieldValue>
</Field>
<Field>
  <FieldName>Track_ID</FieldName>
  <FieldValue></FieldValue>
</Field>
<Field>
  <FieldName>Application_Metadata</FieldName>
  <FieldValue>{"Information Source": "John Doe", "Report": "Imminent attack"}</FieldValue>
</Field>
<Field>
  <FieldName>Application_Metadata_Format</FieldName>
  <FieldValue>application/json</FieldValue>
</Field>
</Metadata>

```

Examining the XML reveals the Spot Report content is located in the “Application Metadata” field in JavaScript Object Notation (JSON) format. This format was selected for compatibility with other tools under development within ARL. The corresponding JSON schema for parsing the spot report content is defined in the following.

```

{
  "$schema": "http://json-schema.org/draft-04/schema#",
  "title": "Spot Report",
  "description": "Attributes Gathered by SpotRep Mobile App",
  "type": "object",
  "properties": {
    "Information Source": {
      "description": "Information Source of Report",
      "type": "string"
    },
    "Report": {
      "description": "Actual Report Content",
      "type": "string"
    }
  },
  "required": ["Information Source", "Report"]
}

```

2.2 Checkpoint Report App

The Checkpoint app was developed to report observations from processing people through checkpoints. The Soldier using the app will also subjectively assign a VoI score (Fig. 4) to the report. Finally, the report is disseminated to analysts for further evaluation. The checkpoint workflow is the same as the spot report workflow and can be found in Section 2.1.

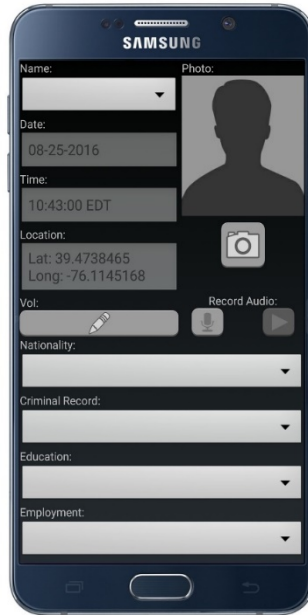


Fig. 4 Checkpoint report main screen

To begin, the Soldier launches the app and is presented with the main screen (Figs. 5 and 6), where report content is recorded.

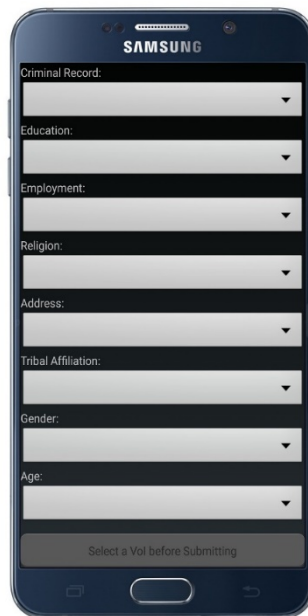


Fig. 5 Checkpoint report main screen 2

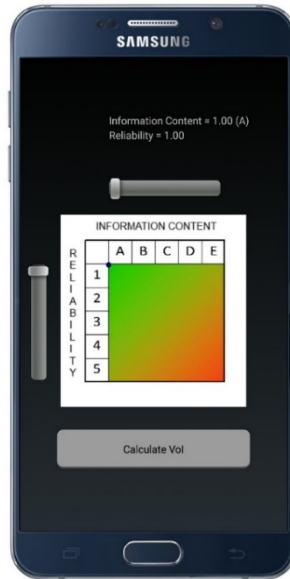


Fig. 6 VoI screen 2

This app was designed with similar design principles as the Spot Report app, so again, simplicity and ease of use were the two main goals. Similar to the Spot Report app, some of the data is automatically generated using the smartphones built-in capabilities. These fields (Data, Time, and Location) are intentionally greyed out to signify that they can't be manually edited. The remaining fields (Name, Nationality, Criminal Record, Education, Employment, Religion, Address, Tribal Affiliation, Gender, and Age) are selectable and the Soldier may complete any combination of fields before submitting the report.

Table 1 shows the data elements in the Checkpoint app along with the range of values.

Table 1 Data elements and values

Data element name	Possible values
Name	Suspect's name
Nationality	Afghan, Muslim,
Criminal record	Has record, no record
Education	High, medium, low
Employment	Cleric, laborer, professional, retired, unemployed
Religion	High, medium, low
Address	Times Square Village, Viet Nam Village, Vertol Village, Hanover Village, Cook Corner Village, Gredge town, Utes Village, Horizon Village
Tribal affiliation	Baloch, Hazara, Pashtu, Tajik
Gender	Male, female
Age	20, 25, 30, 35, 40, 45, 50, 55

The following is an example of output disseminated from the Checkpoint app (DSPro required XML format).

```

<?xml version="1.0"?>
<Metadata>
  <Field>
    <FieldName>Message_ID</FieldName>
    <FieldValue></FieldValue>
  </Field>
  <Field>
    <FieldName>Receiver_Time_Stamp</FieldName>
    <FieldValue></FieldValue>
  </Field>
  <Field>
    <FieldName>Referred_Data_Object_Id</FieldName>
    <FieldValue>APG</FieldValue>
  </Field>
  <Field>
    <FieldName>Referred_Data_Instance_Id</FieldName>
    <FieldValue>41b9832c-6210-4e36-bd12-980577a03d68</FieldValue>
  </Field>
  <Field>
    <FieldName>Pedigree</FieldName>
    <FieldValue></FieldValue>
  </Field>
  <Field>
    <FieldName>Refers_To</FieldName>
    <FieldValue>NO_REF_OBJ</FieldValue>
  </Field>
  <Field>
    <FieldName>Prev_Msg_ID</FieldName>
    <FieldValue>DSPPro-ARL,DSPPro.CheckpointReport:SAMSUNG-SM-N900A:3</FieldValue>
  </Field>
  <Field>
    <FieldName>Source</FieldName>
    <FieldValue>SAMSUNG-SM-N900A</FieldValue>
  </Field>
  <Field>
    <FieldName>Source_Time_Stamp</FieldName>
    <FieldValue>1462300154921</FieldValue>
  </Field>
  <Field>
    <FieldName>Expiration_Time</FieldName>
    <FieldValue>0</FieldValue>
  </Field>
  <Field>
    <FieldName>Relevant_Missions</FieldName>
    <FieldValue></FieldValue>
  </Field>
  <Field>
    <FieldName>Left_Upper_Latitude</FieldName>
    <FieldValue>39.473896</FieldValue>
  </Field>
  <Field>
    <FieldName>Left_Upper_Longitude</FieldName>
    <FieldValue>-76.114525</FieldValue>
  </Field>

```

```

</Field>
<Field>
  <FieldName>Right_Lower_Latitude</FieldName>
  <FieldValue>39.473896</FieldValue>
</Field>
<Field>
  <FieldName>Right_Lower_Longitude</FieldName>
  <FieldValue>-76.114525</FieldValue>
</Field>
<Field>
  <FieldName>Location</FieldName>
  <FieldValue>Times Square Village</FieldValue>
</Field>
<Field>
  <FieldName>Importance</FieldName>
  <FieldValue>9.330000</FieldValue>
</Field>
<Field>
  <FieldName>Source_Reliability</FieldName>
  <FieldValue>1.000000</FieldValue>
</Field>
<Field>
  <FieldName>Information_Content</FieldName>
  <FieldValue>1.000000</FieldValue>
</Field>
<Field>
  <FieldName>Data_Content</FieldName>
  <FieldValue>Checkpoint_Report</FieldValue>
</Field>
<Field>
  <FieldName>Data_Format</FieldName>
  <FieldValue>image/jpeg</FieldValue>
</Field>
<Field>
  <FieldName>Target_ID</FieldName>
  <FieldValue></FieldValue>
</Field>
<Field>
  <FieldName>Target_Role</FieldName>
  <FieldValue></FieldValue>
</Field>
<Field>
  <FieldName>Target_Team</FieldName>
  <FieldValue></FieldValue>
</Field>
<Field>
  <FieldName>Classification</FieldName>
  <FieldValue>Unclassified</FieldValue>
</Field>
<Field>
  <FieldName>Description</FieldName>
  <FieldValue>Checkpoint Report App</FieldValue>
</Field>

```

```

<Field>
  <FieldName>Node_Type</FieldName>
  <FieldValue></FieldValue>
</Field>
<Field>
  <FieldName>Track_ID</FieldName>
  <FieldValue></FieldValue>
</Field>
<Field>
  <FieldName>Application_Metadata</FieldName>
  <FieldValue>{"Name": "Hashim Ahmad", "Nationality": "Afghan", "Tribal
Affiliation": "Baloch", "Age": 30, "Criminal Record": "Has
Record", "Education": "Low", "Employment": "Unemployed", "Religion": "High", "Gender": "Male"}
</FieldValue>
</Field>
<Field>
  <FieldName>Application_Metadata_Format</FieldName>
  <FieldValue>application/json</FieldValue>
</Field>
</Metadata>

```

Examining the XML reveals the Checkpoint content is located in the “Application Metadata” field in JSON format. This format was selected for compatibility with other tools under development within ARL. The corresponding JSON schema for parsing the Checkpoint message is in the following.

```

{
  "$schema": "http://json-schema.org/draft-04/schema#",
  "title": "Checkpoint Report",
  "description": "Attributes Gathered by Checkpoint Mobile App",
  "type": "object",
  "properties": {
    "Name": {
      "description": "Name of the person",
      "type": "string"
    },
    "Nationality": {
      "description": "Nationality of the person",
      "type": "string"
    },
    "Tribal Affiliation": {
      "description": "Tribe of the person",
      "type": "string"
    },
    "Criminal Record": {
      "description": "Criminal Record of the person",
      "type": "string"
    },
    "Education": {
      "description": "Education Level of the person",
      "type": "string"
    },
    "Employment": {
      "description": "Job of the person",
      "type": "string"
    },
    "Religion": {
      "description": "Religion of the person",
      "type": "string"
    },
    "Gender": {
      "description": "Gender of the person",
      "type": "string"
    },
    "Age": {
      "description": "Age of the person",
      "type": "integer"
    }
  },
  "required": ["Name"],
  "optional": ["Nationality", "Tribal Affiliation", "Criminal Record", "Education",
    "Employment", "Religion", "Gender", "Age"]
}

```

2.3 Common Features

The Spot Report and Checkpoint Report apps share numerous features that streamline the Warfighter's report generation process:

- 1) Time and GPS coordinates included in the reports are automatically gathered from the smartphone.

- 2) Ability to include a photograph in the report. The photo can be taken during report creation using the smartphone camera or selected from the phone's gallery. This feature allows the analyst to include a visual depiction of the report content.
- 3) The apps function regardless of network connectivity. Reports will be recorded locally within the device and disseminated whenever a connection is established.
- 4) Audio may be recorded from within the apps. This allows the Soldier to record and disseminate recorded conversations providing the analyst maximum context. There may be a communication barrier during checkpoint operations, but recording conversations prevents information from being lost in the chain from collection to analyst. An analyst may have expert translators available, ready to evaluate audio recordings of interest. When the audio feature is enabled, the corresponding JSON code (Fig. 7) is used to facilitate inclusion of both the photo and audio messages in the data field.
- 5) The apps use the phone's built-in speech-to-text capabilities. The Soldier is not forced to attempt to type on the phone's touch keyboard to input data. There is an optional stylus that may be used to navigate the apps and record text.
- 6) Both apps include a "one-touch" VoI recording option. Touching the VoI grid on the app sets the Source Reliability and Information Content to the corresponding value. Sliders for Source Reliability and Information Content are also available in case isolated control of each field is desired.

The set of streamlined usability features across the apps is designed to allow the Soldier to focus on the mission and avoid struggling with the technology.

```
{
  "data": {
    "picture": [{
      "mimeType": "image/jpeg",
      "bytes": "base64EncodedImage"
    }],
    "audio": [{
      "mimeType": "audio/mpeg",
      "bytes": "base64EncodedAudio"
    }]
  }
}
```

Fig. 7 Data JSON field

2.4 DSPro Integration

This prototype uses DSPro as its dissemination service. DSPro is a technology developed by the IHMC* that efficiently and proactively disseminates information to consumers by means of replication and forwarding policies. The proactive behavior is the result of the integration of policies and a distributed-learning algorithm that takes into account the history of previously requested information, along with the characteristics of the collectors and the mission. As new information becomes available, DSPro matches it against the mission profile and pushes relevant information to the consumers. Information that is selected to be pushed is sorted based on the predicted time to use and the confidence value of the prediction.[†]

In FY16, ARL's Multilingual and Analysis and Battlefield Information Processing groups collaborated with the IHMC to expand and enhance DSPro. As part of that project, DSPro was integrated into the Checkpoint and Spot Report apps. In addition, the VoI metric along with its components (Information Content and Source Reliability) were integrated into DSPro. It's important to note that DSPro takes the VoI score it receives from the smartphone apps and combines it with additional data from other sources to form its own VoI score.

3. Contour

Contour is a software tool developed by Decisive Analytics Corporation (DAC) in collaboration with ARL. It allows an intelligence analyst to collect, search, and analyze large amounts of data. It automatically processes and discovers relationships within the ingested data, which allows the analyst to save time and effort deriving actionable intelligence. Contour's workflow is based on the open source algorithms in Framenet,[‡] Gate, and Annie.[§] These algorithms allow it to generate the relationship diagrams and social network maps.

As mentioned previously, modifying Contour was challenging, as the software was a "black box". With some insight from DAC, ARL was able to incorporate VoI into Contour by overriding the Date field, since date filtering was not of interest in this iteration. Specifically, the year portion of the date field was overridden to represent the VoI score of the data. For example, the year 2000 would represent a VoI score of "0" and the year 2010 would represent a VoI score of "10". With this change

* The Institute for Human and Machine Cognition is a not-for-profit institute of the Florida University System that frequently collaborates with ARL. <http://www.ihmc.us/>.

[†] Getting Started with DisServicePro, Giacomo Benincasa/Niranjan Suri, 2015.

[‡] <https://framenet.icsi.berkeley.edu/fndrupal/>.

[§] <https://gate.ac.uk/>.

implemented, the data set could be modified to include the VoI score for use with Contour.

Figure 8, shows the original Contour social network map for the Ali Baba Data Set. In contrast, Fig. 9 shows the VoI-enhanced social network map for the Ali Baba Data Set. In this example, the VoI filter is set to 5 or greater, resulting in the lower VoI relationships being greyed out. With VoI enhancements enabled, an analyst may quickly triage the information and identify the most important people, organizations, and locations. The links in the graph are extracted from multiple reports, but ARL enhanced the link thickness algorithm to reflect the highest VoI score from amongst those reports.

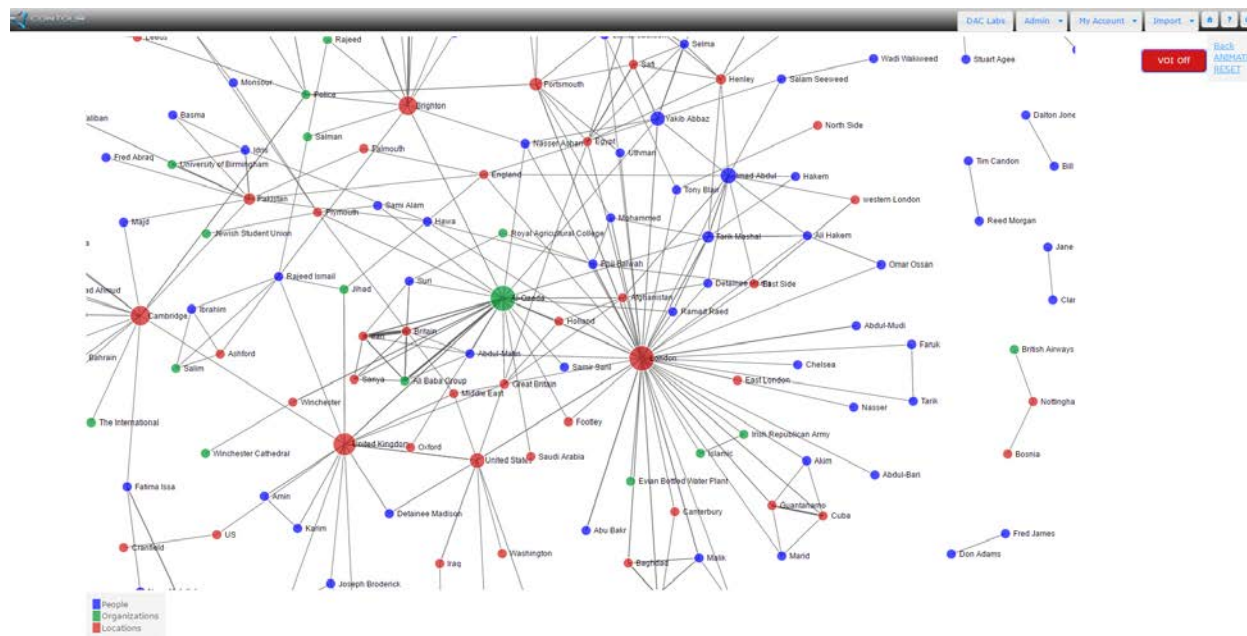


Fig. 8 Contour; no Vol

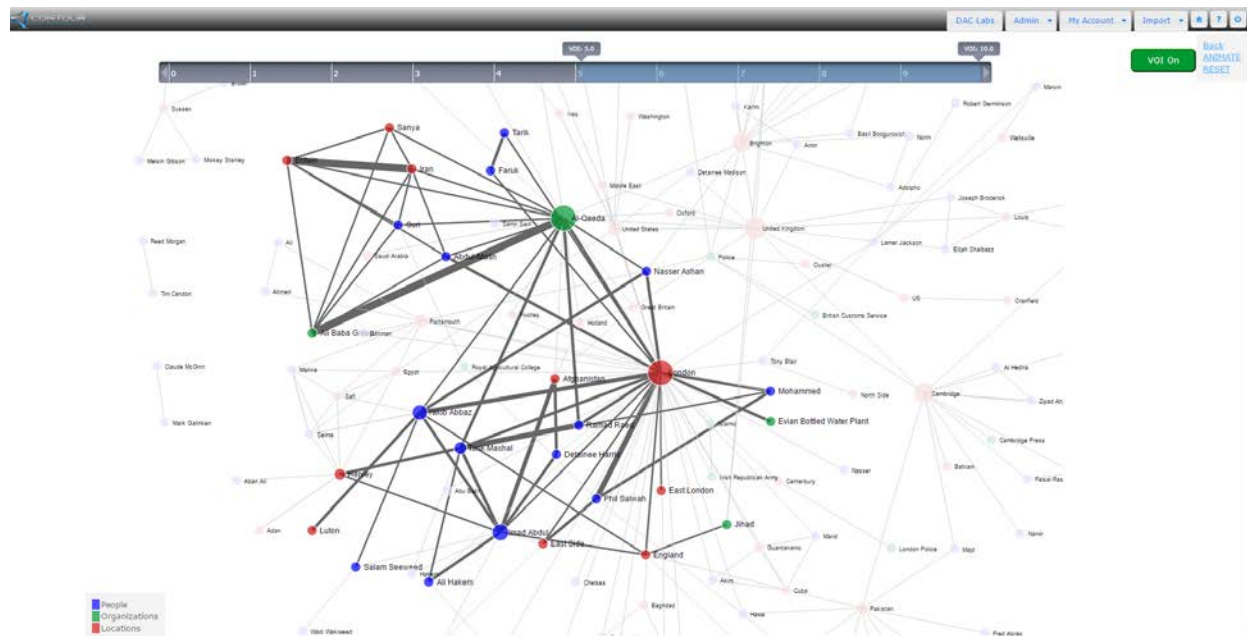


Fig. 9 Contour; Vol

Another issue encountered with Contour was entity recognition. To illustrate, Contour does not recognize Arabic names. This issue was identified when Contour's social network graph was compared to ground truth and found to be incomplete. To correct this, the Contour gazetteer or "whitelist" was modified to include all of the unique names and locations in the dataset. This method resolved most of the name issues; however, a few names had to be modified to be recognized by Contour. It is believed that the upcoming version of Contour will fix this problem.

Testing the enhanced version of Contour required a data set with a known ground truth. Consequently, the Ali Baba Data Set was selected. ARL is familiar with the Ali Baba Data Set from past experience.⁵ The data set contains 625 messages in individual text (.txt) files, which contain 1 or 2 short sentences. As mentioned previously, the data set had to be manipulated to be compatible with Contour. This entailed assigning the 625 documents a VoI score (by overriding the date field) and fixing formatting issues. ARL expertise with the dataset allowed for learned application of VoI scores. These modifications allowed the team to ingest the data set into Contour and successfully exercise the resulting relationship graph with VoI filters.

4. Conclusions

ARL has developed a prototype system that incorporates VoI from collection to analysis. This system is a candidate platform for field experiments to evaluate the benefits of VoI.

ARL's Checkpoint and Spot Report apps allow Soldiers, as data collectors, to send VoI-rated data, derived from their subject matter expertise, from the field back to the analyst. The data traverses the DSPro network, which may add additional VoI-based filtering, before being analyzed by VoI-enhanced tools, such as the augmented version of Contour.

Simulations suggest that VoI-rated data aid the analyst in processing the most valuable intelligence first, which is an important component sustaining situational awareness. This prototype will allow further investigation of the benefit of VoI in a field environment. If future field exercises are successful, this would be the first step in developing a system for aiding the analyst to rapidly discover the most valuable information being collected real-time in the field.

5. References

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List of Symbols, Abbrevations, and Acronyms

app	application
ARL	US Army Research Laboratory
DAC	Decisive Analytics Corporation
GPS	global positioning system
IHMC	Institute for Human and Machine Cognition
JSON	JavaScript Object Notation
SME	subject matter expert
VoI	Value of Information
XML	Extensible Markup Language

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